The diet of the re-introduced greater bilby *Macrotis lagotis* in the mallee woodlands of western New South Wales

Mangala Navnith[1], Graeme R. Finlayson[1,3], Mathew S. Crowther[1,2] and Chris R. Dickman[1]

[1] Institute of Wildlife Research, School of Biological Sciences, University of Sydney, Sydney, NSW 2000

[2] Vertebrate Ecology Unit, Biodiversity Conservation Science, Scientific Services, Department of Environment & Climate Change, PO Box 1967, Hurstville, NSW 2220

[3] Corresponding author. Email: graeme.finlayson@bio.usyd.edu.au

ABSTRACT

The greater bilby *Macrotis lagotis* once occupied about 70% of the Australian mainland but is now restricted in occurrence to just 20% of its former range. It is classified as Extinct in New South Wales. We assessed the major components of the diet of a recently re-introduced population of bilbies at Scotia Sanctuary, in western New South Wales, from faecal material collected over a period of 13 months. Animals consumed more invertebrates than green plant material and seeds throughout the study, although there was temporal variation in the presence of these food categories. Five orders of invertebrates were identified, with Coleoptera (beetles) occurring in more than 80% of faecal samples and Isoptera (termites) and Formicidae (ants) in 48% and 40%, respectively. These results identify key components of the diet of the first population of bilbies in New South Wales since the early 20th century and, combined with detailed studies of habitat requirements and prey abundance, should assist with selection of additional sites to expand the distribution of this iconic species further in future.

Key words: Bilby, *Macrotis lagotis*, diet, mallee, re-introduction

Introduction

The greater bilby *Macrotis lagotis* is a medium-sized (800-2500 g), sexually dimorphic and semi-fossorial member of the marsupial family Thylacomyidae (Johnson and Johnson 1983; Johnson 1989; Johnson 1995; McRae 2004). The species is considered to be omnivorous, eating insects, bulbs, roots, seeds and fruits at different times (Smyth and Philpott 1968; Watts 1969; Gibson 2001; Southgate and Carthew 2006; Bice and Moseby 2008).

Prior to European settlement, the bilby was widespread and common west of the Great Dividing Range in eastern Australia; its range covered 70% of the Australian mainland (Watts 1969; Southgate 1990). The bilby became extinct in New South Wales in the early 20th century (Troughton 1962; Ashby *et al.* 1990; Lunney 2001), with the last known live specimens collected near Wagga in 1912 (Troughton 1932). Elsewhere it is now restricted to small, isolated populations scattered across approximately 20% of its former range (Southgate 1990) in the Tanami Desert, Northern Territory (Johnson and Southgate 1990; Johnson 1995), the Great Sandy and Gibson Deserts, Western Australia (Smyth and Philpott 1968; Friend 1990; Johnson 1995) and in the Channel Country of south-western Queensland (Watts 1969; Gordon *et al.* 1990; Johnson 1995; McRae 2004). The bilby is within the identified critical weight range (CWR) of medium-sized mammals (35-5500 g) that have suffered large-scale range reductions and at least 22 extinctions since European settlement (Burbidge and McKenzie 1989; McKenzie *et al.* 2007). Several factors are likely to have contributed to the decline of the bilby, including the expansion and intensification of the pastoral industry, competition with the European rabbit *Oryctolagus cuniculus* and predation from introduced predators such as the red fox *Vulpes vulpes* and feral cat *Felis catus* (Catling 1988; Myers *et al.* 1989; Morton 1990; Lunney 2001).

As a result of its dramatic decline, the bilby has been translocated or re-introduced to protected mainland reserves or to predator-free offshore islands in South Australia (DEH 2003; Moseby and O'Donnell 2003; Bentley and Schmitz 2004; DEH 2005), Western Australia (Friend and Beecham 2003; Mawson 2004; Morris *et al.* 2004), Northern Territory (Southgate *et al.* 1994) and Queensland (ABC 2003). Most recently, it has been re-introduced into a predator-free reserve at Scotia Sanctuary in western New South Wales (Finlayson *et al.* 2008). Studies of the biology of the bilby in these re-introduced populations will allow assessment of the success of the re-introductions and also assist in selecting further re-introduction sites, which are essential for the recovery of this species (Pavey 2006). In this study, we describe the dietary components of the re-introduced greater bilby colony at Scotia Sanctuary over a 13-month period in the initial stages after release into the reserve.

Methods

Study Area

Scotia Sanctuary (64 000 ha; 141º 10´ E, 33º 10' S) lies 150 km south of Broken Hill, on the boundary of the arid and semi-arid climatic zones. Rainfall averages 257 mm a year and is highly irregular. The region endures hot summers with mean daily temperatures of 17–33ºC and cool winters with mean daily temperatures of 5–17ºC. Dominant landforms include east-west parallel sand dunes with narrow sandy swales and open calcareous swales of varying width.

Within the sanctuary, 4000 ha of relatively intact woodland and shrub have been fenced, and all introduced large and medium-sized mammals (foxes, cats, goats *Capra hircus* and rabbits) eradicated. Since November 2004 a series of re-introductions has been carried out, with greater bilbies, numbats *Myrmecobius fasciatus*, burrowing bettongs *Bettongia lesueur*, brush-tailed bettongs *B. penicillata*, and bridled nailtail wallabies *Onychogalea fraenata* being experimentally released into the fenced area. Four dominant vegetation communities occur within the fenced site: *Eucalyptus* woodland (mallee) with an understorey of *Triodia scariosa* (spinifex); mallee over a variety of shrubs; *Casuarina pauper* woodland (belah); and shrubland (previously cleared woodland undergoing regeneration). Dominant *Eucalyptus* species are *E. oleosa*, *E. costata, E. dumosa,* and *E. socialis* (J. Bentley *pers. comm.*). Frequently occurring grasses and herbs in these communities include *Austrostipa* spp., *Vittadinia cuneata* complex, *Dissocarpus paradoxus*, *Chenopodium cristatum* and *Podolepis capillaris* (Westbrooke *et al.* 1998). Despite previous land clearing within the area, Scotia Sanctuary has a short grazing history, and only small areas of woodland have been burnt in the release site since 1975. The sanctuary supports some of the most intact mallee-belah woodland in the region.

Animal Trapping

Trapping sessions were carried out every three months between June 2005 and June 2006. A network of 114 trap sites was established along tracks within the reserve, with each trap site containing three wire cage traps (small: 57 × 23 × 23 cm; medium: 62 × 25 × 25 cm; and large: 76 × 33 × 32 cm), each being spaced about 500 m from its nearest neighbour. Traps were set at dusk, covered in hessian sacks to protect animals from the elements, and baited with a mixture of rolled oats, peanut butter, honey and vanilla essence. Traps were checked 2–3 hours after sunset and fresh faeces found in the traps were collected and stored in airtight snap-lock bags and then frozen until analysis.

Faecal Analysis

A single pellet was selected at random from each of the 26 collected faecal samples, placed in a petri dish in water for 15-20 minutes, and then teased apart with a dissection needle and forceps. A small amount of water was added to evenly suspend the faecal material, which was then observed under a dissecting microscope. Once the contents of the sample were identified a 1 cm^2 grid was attached to the bottom of the petri dish to estimate the percentage volume of the different food categories. Three categories were recognised; invertebrates, plant material and other (seeds, fungi, unidentifiable material, soil and other items). Where possible, we classified invertebrates to order. General plant material, including root, leaf and stem, was classified as 'plant' (Table 1); seeds were classified separately. A total of 107 bilbies were trapped during the duration of this study however not all captured bilbies provided a faecal sample for this study. Due to low rates of capture during each of only 21 bilbies per trapping session (G. Finlayson, *unpublished data*), the number of samples per sampling period was not constant and the overall sample size was small. Faecal samples were collected from five bilbies in June, five in September, eight in December 2005, three in March and five in June 2006, allowing us to assess variation in dietary composition across these months. One single pellet from each faecal sample collected was used for the dietary analysis.

Table 1. Overall dietary composition of the greater bilby at Scotia Sanctuary expressed as the frequency of occurrence of prey items in all sampled faecal pellets (%). Insignificant traces of fungal material were identified (+).

Prey item	Frequency of occurrence (%)
Invertebrates	
Hymenoptera (Formicidae)	40
Isoptera	48
Coleoptera	84
Blattodea	16
Araneae	4
Plant material	
General plant material (leaf/root/tuber)	80
Seed type1	4
Seed type 2 (grass seed)	20
Seed type 3	16
Fungi	+
Unknown	100
Soil and other items	100

Data Analysis

We described the diet in two ways, firstly as the percentage frequency of occurrence of different food categories across all pellets sampled, and secondly, as the percentage volume of the pellets that these categories occupied. To compare the composition of pellets between sampling periods, we used non-metric multidimensional scaling (nMDS) based on a Bray-Curtis similarity matrix. We tested for statistical differences between months using ANOSIM (Analysis of Similarities) in PRIMER version 5.0 (Clarke 1993).

Results

Twenty-six samples were analysed, three from March 2006, eight from December 2005, and five each from the other months. A plot of prey type diversity against sample size levelled off after 9-10 samples, indicating that the overall number of samples used was sufficient to describe reliably the overall diet of the bilby.

Overall dietary composition

1. Invertebrates

We recorded invertebrates in 92.3% of the pellets analysed, with Isoptera (termites), Coleoptera (beetles), Hymenoptera (all Formicidae; ants), Araneae (spiders) and Blattodea (cockroaches) being represented (Table 1). Coleopterans occurred most frequently, followed by Isoptera and Hymenoptera. The latter two groups were identified mostly by mouthparts and head capsules; if ants were very small (<2 mm) the entire body could be observed. Most coleopterans were adults, although a larva was found in one sample. The remains of Blattodea and Aranea were found infrequently (Table 1).

2. Plants

General plant material occurred in 80% of the pellets analysed, considerably more frequently than three types of seed that could be distinguished (Table 1). Two of the seed types could not be identified, but the most common seeds were from one (or more) species of grass (seed type 2; Table 1). In the December 2005 sample, these were the only seeds observed. In the March 2006 sample, we found grass seeds and an unidentified species with a hard outer coat that had been broken into pieces (seed type 1). The third seed (type 3) occurred in samples from the three remaining months.

3. Fungi

The only fungi identified in the faecal material of bilbies at Scotia Sanctuary were two species of monosporic fungi; *Acaulospora laevis* and an unidentified species (P. McGee *pers. comm.*). These represented an extremely small fraction (< 1%) of the overall diet.

4. Unknown

This group included unidentifiable plant material, invertebrate parts and other microscopic pieces that were difficult to identify. These items occurred in all samples analysed, but always formed a small component (8-15%) of pellet volume.

5. Soil and other items

We found skink eggs in two faecal pellets in March 2006 and hair in another pellet in December 2005. Soil was present in all the samples and was a large component of each pellet (Table 1). The type and the quantity of soil showed some variation between faecal samples, perhaps reflecting different foraging substrates used by bilbies.

Temporal Variation

The percentage volume of invertebrates in the diet of bilbies was consistently higher than that of plants across all sampling periods, especially in December 2005 and March 2006 (Fig. 1). Among invertebrates, coleopterans predominated in the diet in all months except December 2005, when Isoptera were ascendant, and March 2006, when the consumption of Coleoptera and Isoptera was the same (Fig. 2). Hymenoptera (Formicidae) peaked in the diet samples in December 2005 and Blattodea in June 2005; Aranea appeared once only, in June 2006 (Fig. 2). Analysis of similarities confirmed that these monthly differences in dietary composition were significant (Fig. 3, overall Global R = 0.35, p = 0.001); with differences detected between March 2006 and September 2005 (Global R = 0.585, p = 0.018), March 2006 and June 2005 (Global R = 0.559, p = 0.018), March 2006 and December 2005 (Global R = 0.426, p = 0.012), June

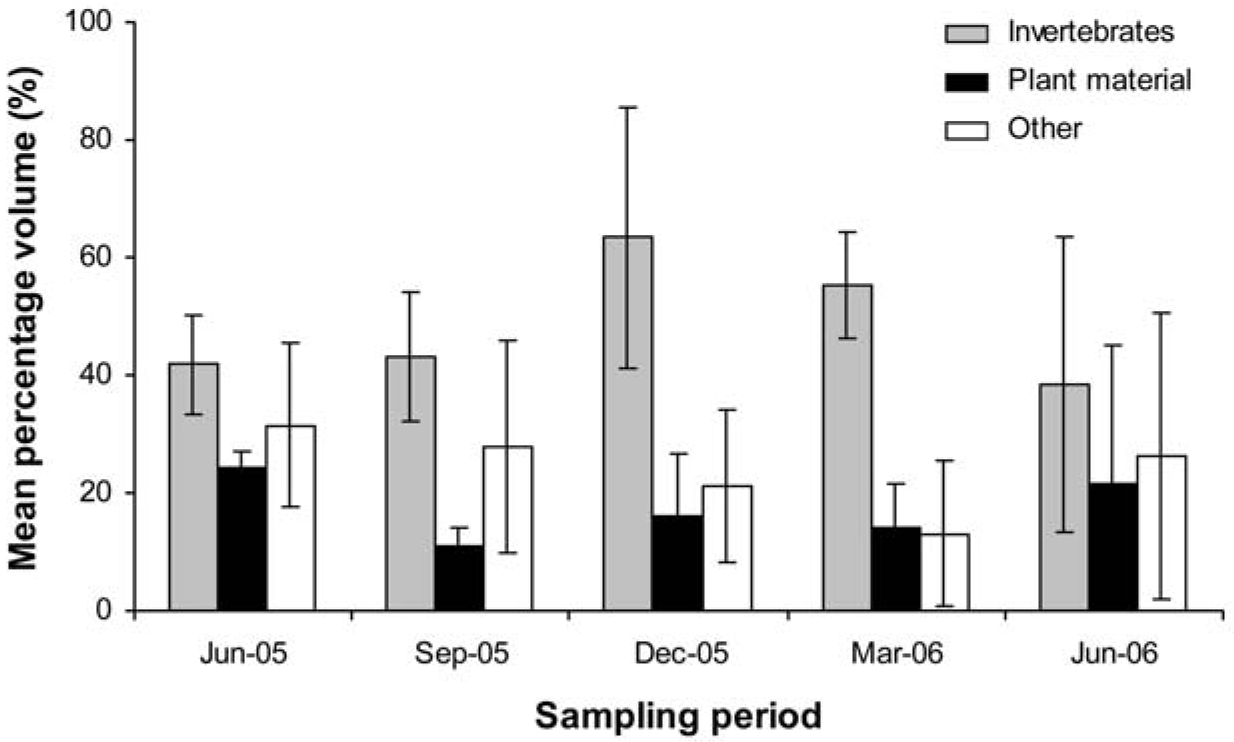

Figure 1. Percentage volumes of invertebrates, plant material and other material (seeds, skink eggs, unidentifiable objects, fungi and soil) identified in bilby faecal material collected at Scotia Sanctuary over five sampling periods between June 2005 and June 2006. Error bars represent standard deviation from the mean.

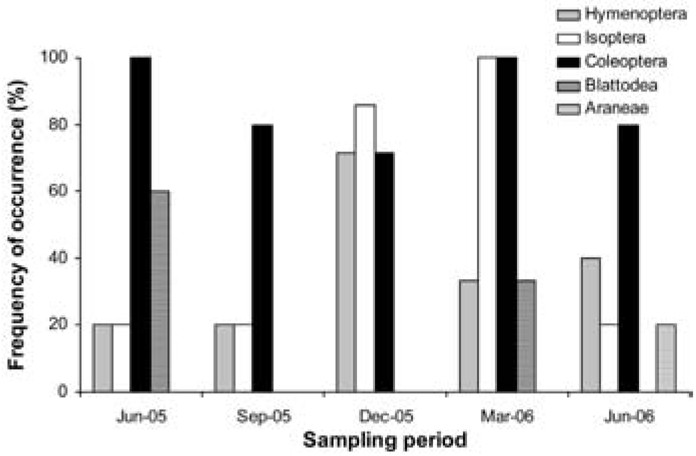

Figure 2. Percentage frequency of occurrence of invertebrate prey items identified in bilby faecal material collected at Scotia Sanctuary over five sampling periods between June 2005 and June 2006.

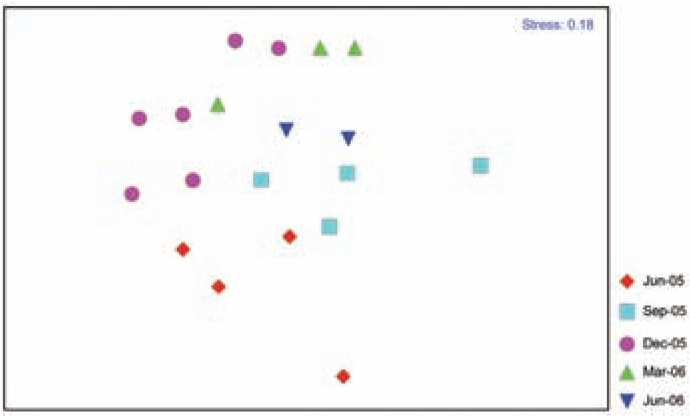

Figure 3. Non-metric multidimensional scaling plot showing differences in the composition of bilby diets at Scotia Sanctuary over five sampling periods between June 2005 and June 2006.

2006 and June 2005 (Global R = 0.284, p = 0.024), June 2006 and December 2005 (Global R = 0.563, p = 0.002), September 2005 and December 2005 (Global R = 0.519, p = 0.004), and June 2005 and December 2005 (Global R = 0.371, p = 0.006).

Discussion

Our results show that bilbies at Scotia ate a wide range of foods from above and below the ground surface, thus supporting the findings of previous studies. In the Tanami Desert, Southgate and Carthew (2006) recorded bilbies eating seeds, especially from the grasses *Dactyloctenium radulans* and *Yakirra australiense*, underground bulbs (*Cyperus bulbosus*), fungi (Endogonacae), adult invertebrates and invertebrate larvae and eggs (Coleoptera, Lepidoptera, Orthoptera). Gibson and Hume (2000) also commented on the dietary flexibility of the bilby.

Despite consuming diverse prey, the diet of bilbies at Scotia was dominated by invertebrates, especially by Coleoptera. Bilbies have been reported to eat beetles and other insects previously (e.g., Watts 1969; Gibson 2001), with some work indicating that isopterans are especially important (Smyth and Philpott 1968; Bradshaw *et al.* 1994; Southgate *et al.* 1996; Keiper and Johnson 2004; Southgate and Carthew 2006). It is not clear whether bilbies favour some types of invertebrates more than others, or simply eat what is most abundant or accessible, although Gibson (2001) suggested that prey availability may have the strongest influence on diet. Scotia was in drought for the duration of our study; this could have driven termites deep into the soil and thus have made them less readily available than surface-active beetles. Green plant material and seeds also contributed relatively less to the diet than reported in other studies (Gibson 2001; Southgate and Carthew 2006). This may reflect the paucity of forbs and other non-woody vegetation during the drought at Scotia, or possibly competition with re-introduced bridled nailtail wallabies and bettongs in the reserve that also consumed some seeds (G. Finlayson *pers. obs*).

Despite fungi being recorded as an important component of bilby diet in previous studies (Southgate and Carthew 2006), we recorded fungi only in trace amounts in the diet of re-introduced bilbies here. The few identified fungal spores that we found were monosporic and thus likely to be found singly in the soil (P. McGee *pers. comm.*), so they could have been consumed opportunistically while digging. We noted very few fungal fruiting bodies at Scotia, perhaps owing to the dry conditions that prevailed throughout the study period. The fruiting bodies of hypogeous fungi are important components of the diet of a number of medium-sized marsupials (Claridge and May 1994; Claridge *et al.* 2007), but generally these are associated with areas of higher rainfall. Dietary analyses of other re-introduced species (*Bettongia* spp.) at Scotia Sanctuary have similarly failed to detect fungi (G. Finlayson *pers. obs.*).

The consumption of skink eggs by bilbies has not been recorded previously. It is possible that the eggs were eaten accidentally by bilbies while foraging for other dietary items, such as larvae, which have been reported as a component of bilby diet by Aboriginal people in other parts of the species' range (Burbidge *et al.* 1988) and which we also found here. However, it is most likely that such an opportunistic forager as the bilby would simply consume alternative (and readily available) prey items when encountered.

Although some dietary items such as green plant material and beetles were probably obtained from the soil surface, the high incidence of soil in faecal pellets suggests that they dig for most of their prey. Subterranean foods might include termites and ants, burrow-dwelling spiders and plant roots. Although not quantified, we observed obvious differences in the types of soils within pellets across the five sampling periods. This probably indicates that bilbies foraged wherever food was available, irrespective of substrate or vegetation type. We have found no evidence that bilbies prefer certain habitats when active at Scotia (Finlayson *et al.* 2008), thus supporting the inference that animals forage widely to meet their food requirements.

We found marked temporal shifts in the diet of bilbies at Scotia, which is similar to that reported by previous studies. The most obvious difference was that invertebrates were eaten more frequently and in greater volume in summer (December and March) than at other times. Other studies have shown similarly that bilbies turn their foraging efforts

to insects during the hotter months (Johnson and Johnson 1983; Southgate 1990). In contrast to the findings of Gibson (2001) that plant material remained more or less constant in the diet between seasons, however, we found that plant material contributed little to the diet during summer. The predominance of invertebrates that we found in the summer diet may reflect easier access to invertebrates at this time (either through abundance, or increased activity and hence more visible and/or obtainable), a reduction in green forage that is available during the hot and dry conditions, or a seasonal switch in dietary preferences.

Detailed studies of the resources used by animals often provide essential information for conservation and management decisions (Cox *et al.* 2000; Pizzuto *et al.* 2008). In re-introduction programs, it is especially important to carry out rigorous post-release monitoring of the resource use and demography of newly-establishing populations to assess their survival. In this study, we confirm the adaptable dietary capabilities of the bilby, but also highlight the importance of invertebrates. Access to this food source is probably critical for re-introduction success at Scotia Sanctuary, where two re-introduced species of bettongs, the numbat and bridled nailtail wallaby may compete for other components of the resource base (Finlayson *et al.* 2007; Vieira *et al.* 2007). Our results provide hope that the bilby can still survive in altered landscapes where it once thrived. Further examination of the habitat, diet, distribution and density of the favoured prey items of the bilby should assist with site selection when considering future re-introductions of this species into other parts of its former range in both New South Wales and other parts of Australia.

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APPENDIX I

Bilby at Scotia.

Photo: Emilie Kissler.